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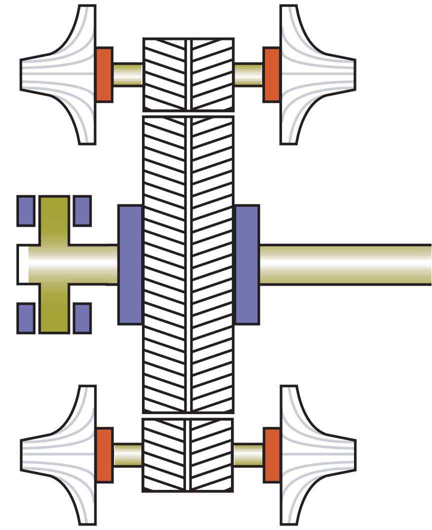

Diagnosing an Oil-Related Problem in an Air Compressor

Technologies such as lubrication analysis provide new insights into machinery condition and complement the condition monitoring capabilities of vibration analysis. Bently Nevada's Machinery Diagnostic Services (MDS) and Asset Care (AC) Teams utilize these and other tools to help our customers solve difficult machinery problems. This case history discusses the importance of integrating such technologies in a predictive maintenance environment.

"With the increasing vibration, bearing wear was one possible concern."

Background

Earlier this year, Bently Nevada's MDS team was contacted to diagnose a problem on a customer's large, four-stage, integrally geared air compressor. Figure 1 shows the overall machinery layout and lists some pertinent data. Both of the compressor's pinion shafts are supported by two radial bearings each, and each bearing is monitored with one Bently Nevada proximity probe mounted adjacent to the bearing to measure shaft vibration relative to the bearing housing. These probes are in turn connected to a Bently Nevada 3300 Series permanent vibration monitoring system. The motor and bull gear rotors are supported by two sleeve bearings each, but are not permanently instrumented with any vibration monitoring equipment. Such limited vibration instrumentation (lack of XY radial probes, lack of Keyphasor® probe, no transducers on bull gear or motor), though not considered adequate for proper machinery diagnostic capabilities, is typical of that supplied on integrally geared compressor designs. Not surprisingly, vibration analysis was hampered by the relatively sparse complement of transducers.

Data for this case history was acquired using a Bently Nevada Snapshot™ for Windows® CE portable data collector and our System 1™ software platform. The Snapshot™ instrument was connected to the 3300 monitors for acquiring vibration data from the

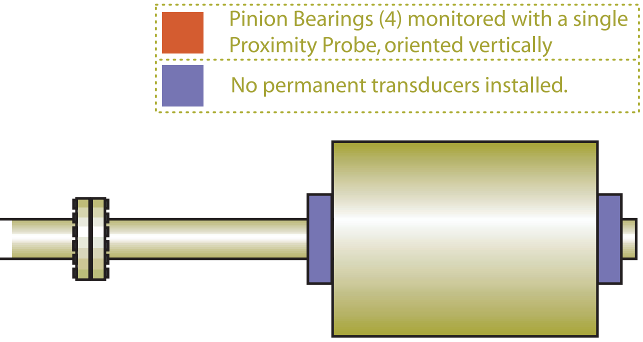

FIGURE 1

MACHINERY ARRANGEMENT AND DATA

	SPEED	RATING
MOTOR	1,790 rpm	3,500 hp
STAGES 1-2	16,080 rpm	Stages 1-3 = 18,760 ACFM
STAGES 3-4	18,760 rpm	Stage 4 = 875 ACFM

compressor, while a temporary transducer was used to take data from the motor and bull gear bearings. Pertinent process data points were also configured in System 1™ and sampled for correlation with the vibration data.

Vibration Analysis

The plant's predictive maintenance (PdM) program had identified gradual but continually rising vibration levels on the compressor's 3rd and 4th stages during the past several surveys. Shaft vibration of about 1.0 mil peak-to-peak (mil pp) was observed when MDS was on site. These levels were considered to be only marginally acceptable for long-term operation. Analysis of the proximity probe half spectra revealed dominant 1X vibration at each measurement location. Figure 2 shows the half spectrum from the 3rd stage bearing. Vibration measured at the 1st and 2nd stage rotors was lower, 0.6 mil pp and 0.8 mil pp respectively, with dominant 1X components as well.

With the increasing vibration, bearing wear was one possible concern. To help assess bearing wear, the proximity probe

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Half Spectrum from 3rd Stage Compressor Bearing

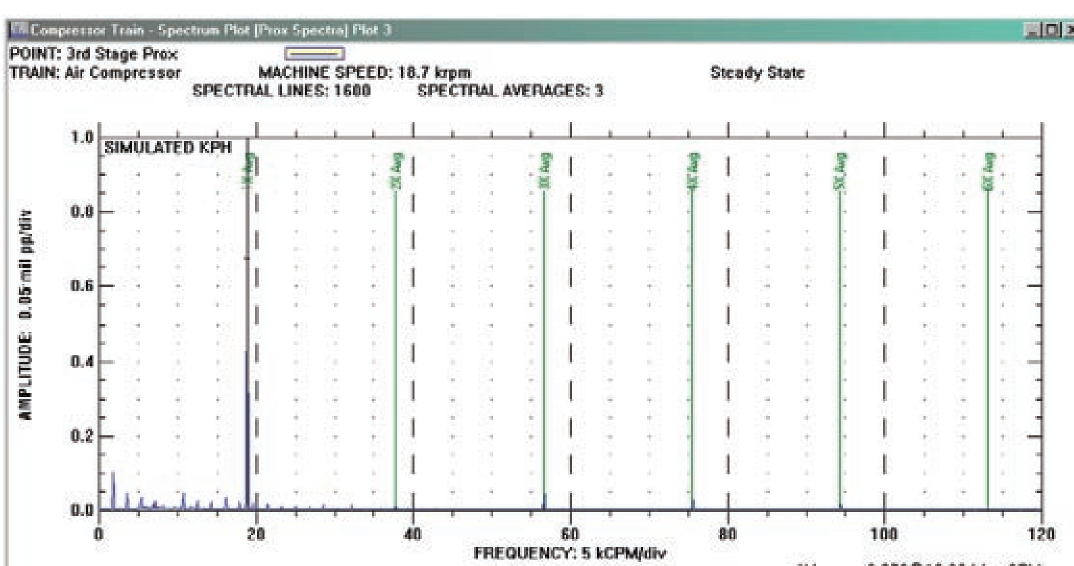

FIGURE 2

"Bently Nevada has observed numerous bearing failures resulting from misapplication of these types of oils in the past."

dc gap voltages can be checked. It is important to remember that proximity probes provide two important measurements: the shaft-relative vibration (the ac voltage component), and the average distance (gap) from the shaft surface to the probe tip (the dc voltage component). By trending the dc gap voltages over time, it can be ascertained whether the shaft is moving away from the probe tip as a result of babbit wear or other forces. Unfortunately, the portable data collector used by the plant did not measure and trend the dc voltage components to provide an historical record of shaft movement. MDS turned to a study of the plant's maintenance records and historical lubrication analysis records for further clues.

Maintenance Records

Plant personnel related that during the two previous inspections, various degrees of coking were observed on the compressor's 3rd and 4th stage bearings. This necessitated bearing replacement, and along with materials and labor, cost the plant about $4,000 USD each. Coking, or carbon deposits, often results from lubricant oxidation. This is the formation of partially oxidized organic compounds resulting from high temperatures, high mechanical stresses, and/or reaction with certain contaminants in the lubricant, in the presence of oxygen. Sludges and varnishes are typical by-products of the early stages of oxidation. With further oxidation, these by-products are converted into aggressive carboxylic acids that can corrode many machine component surfaces.

Lubrication Analysis

As part of the plant's PdM program, the lubricant had been sampled quarterly for independent laboratory analysis. MDS reviewed the most recent data and found the following:

- 3 ppm copper – a likely bearing constituent and a contaminant that accelerates oxidation.
- 10 ppm silicon – particulate contamination due to poor filtration of ambient air.

PARTICLE COUNT TREND RESULTS

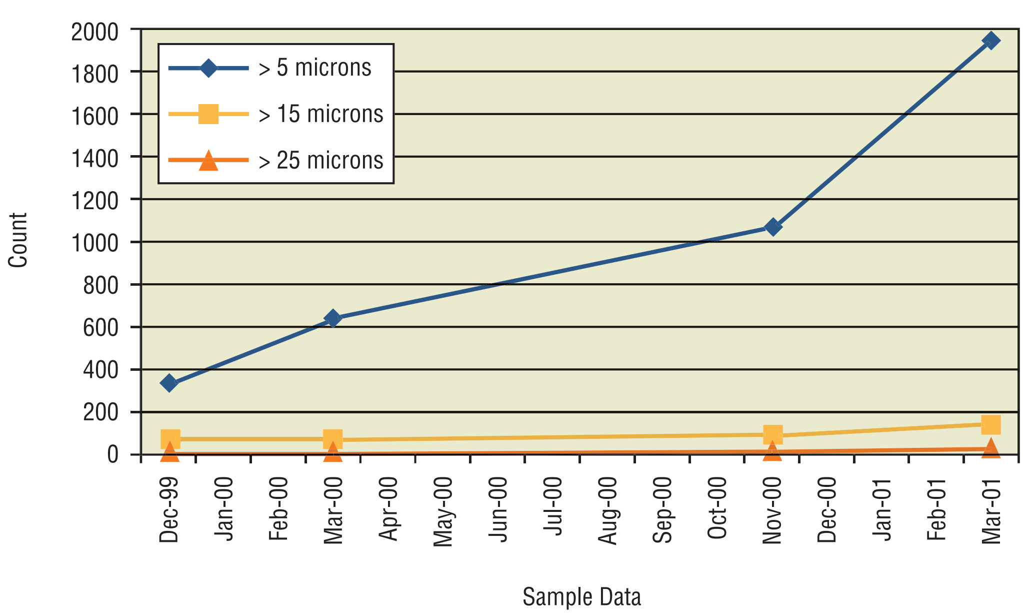

FIGURE 3

- Water listed as "< 0.1%" (< 1,000 ppm) – a coarse measurement.
- 39 ppm zinc (an additive) – lowest level since March 2000, and trending down.
- 70 ppm phosphorus (an additive) – at the low end of the observed range.
- 36.4 cSt viscosity (@ 40 °C) – this is 15.2% above the lube sample reference value of 31.6 cSt.
- Particulate counts were at their highest historical levels and trending upward, indicating accumulating contamination within the oil system (Figure 3).

LUBE OIL PROPERTY COMPARISON

			Kinematic Viscosity			
Type	Pour Point °F	Flash Point °F	cSt @ 40 °C	cSt @ 100 °C	Viscosity Index	ISO Viscosity Grade
Existing Lubricant	20°	400°	30.4	5.1	95	32
Recommended PAO Synthetic	-55°	440°	32.0	6.0	138	32

TABLE 1

Although no single item in the list above would normally trigger an alarm or individually point to the machine's lubricant as the primary problem, they collectively indicated that the oil's additives were being depleted, bearing wear was likely occurring, and the observed machinery problems might well be related to its lubricant. As a result, a closer investigation of the lubricant was undertaken and MDS revisited the machine's maintenance records for possible insight.

Root Cause

The records revealed that the original lube charge, a light, mineral-based turbine oil, had been used since operation began in 1995. Since that time, only make-up oil had been added as necessary. The lubricant properties of this oil indicate that it is generally best reserved for applications that run cool, have relatively lower speeds involved, and are not subject to extreme cold. Bently Nevada has observed numerous bearing failures resulting from misapplication of these types of oils in the past, typically in higher speed, higher temperature applications.

Recommendations

Upon review of the observed vibration, oil analysis, and maintenance data, the following recommendations were made to improve the reliability of this compressor:

- A bearing inspection should be performed and the clearances precisely checked. Even slightly over tolerance bearings will result in increased vibration due to lower Dynamic Stiffness.
- A synthetic, polyalphaolefin (PAO)-based lubricant should be utilized to provide improved lubrication properties (Table 1). For this application, the most important properties are the pour point and Viscosity Index (see sidebar).
- Thorough cleaning of the lube tank prior to refilling with new oil, in order to avoid contamination from residual particulate matter.
- The unit should then be run for 8 to 10 hours to thoroughly flush the system, the oil should be drained, and the tank refilled.
- Karl Fischer analysis (ASTM D1744) should be used in place of the current "crackle test" for future water analysis. The crackle test is relatively insensitive, only detecting moisture content greater than 0.05% (500 ppm). Experience has shown that water levels as low as 200 ppm to 300 ppm have a definitive, detrimental effect on the oil's lubricating properties and overall life span, and also promote corrosion. ASTM D1744 provides accuracy to 0.001% (10 ppm) and quantifies both the emulsified and free water. The increased cost per oil sample is minimal compared to the data that is obtained and its potential implications.
- With the accumulating particulate contamination, an inspection of the filter house was recommended to detect any clogged or failing filter media. Consideration of a finer filter media was also recommended to improve filtration. Minor suction losses from finer media would not pose a problem, as the plant uses less than 75% of the compressor's full capacity.

Summary

The goal of any predictive maintenance program is increased reliability and availability with minimized maintenance costs. This case history highlights the necessity for the involvement of trained specialists in a plant's predictive maintenance efforts, both to identify the proper type of data to collect and then to analyze the collected data. In this situation, limited data was being gathered – vibration and lubrication condition at regular intervals – but no trained resource was available at the plant to effectively correlate and analyze the data. Also, the type of data being gathered was not as complete as desirable, such as noted earlier by the need for probe gap voltage trends to indicate bearing wear and a more capable test regimen (Karl Fischer) for detecting the presence of water in the lubricant.

Bently Nevada's Machinery Diagnostics and Asset Care Teams utilize our own skills in machinery vibration analysis, coupled with the oil analysis expertise of National Tribology Services, to assist you with cost-effective and comprehensive lubricant analysis and machinery troubleshooting. Contact your local Bently Nevada sales or service professional for further information regarding our scope of capabilities. ORBIT

A Case for Synthetic Lubricants

Kinematic viscosity is a measure of a lubricant's internal friction, or resistance to flow. This is essentially its ability to maintain a lubricating film between moving surfaces and is likely the most important parameter to maintain. Many PAO-based synthetic lubricants provide a higher viscosity reading across their range of temperatures compared to mineral-based oils.

Viscosity Index (VI) describes a lubricant's viscosity stability as a function of temperature. The higher the VI, the better the lubricant will resist high temperature viscosity changes. VI can also be roughly looked at as a lubricant's ability to resist oxidation. Synthetic lubricants generally offer significantly higher VI values than mineral oils.

Pour point measures the lowest temperature at which a lubricant will freely pour, and is important for machinery located outdoors. Even though this machine was equipped with a lube oil warming mechanism, the synthetic oil's much lower pour point will ensure adequate lubrication during cold starts. Synthetic oils do not possess the waxy crystalline structures found in paraffinic mineral oils, and thus have significantly lower pour points.

Flash point determines at what point the lubricant vapor will flash in the presence of an open flame. The synthetic lubricant's higher flash point provides an increased safety margin in the event of any oil leaks that would result in lubricant vapors that could be ignited. ORBIT